

Docket No. SA-525

Exhibit No. #9B

NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

Systems Group Chairperson's
Pressurization and Pneumatic Modeling Exhibit

(30 Pages)

Exhibit Section 1.0

Systems Group Chairman's Factual Extracts:

The following tables pertain to the APU and are copied from the Systems Group Chairman's Factual Report of February 9, 2005

APU pneumatic bleed data and requirements:¹

	Ambient Temp (F)	Altitude (ft)	Bleed flow (ppm)	Bleed Pressure (psia)	Bleed Temp (F)	Exhaust Gas Temp (F)	Generator load (KVA)
Specified minimum bleed for new APU ²	103	Sea level	60.0	53.8	504	1050 nominal, 1320 maximum	15 (minimum)
	9.3	13,000	49.4	35.1	424	1315	[None]
	The above two rows show data from the new engine minimum bleed performance table for the GTCP36-150[RJ]. The first row is data quoted from the Allied Signal Aerospace 36-150[RJ] APU Troubleshooting Guide, dated May 28, 1996 (document 31-13177). The second row depicts a Honeywell-supplied performance calculation that is based on running a mathematical model at the exhaust temperature limit of the APU. See the performance table and specific test results for more detailed information in the section titled Attachments.						
APU from N8396A, during pneumatic load of a main engine start.	69.0	1,250	79.0 [78.0 required minimum value]	50.6 [47.7 required minimum value]	458.9 (raw data, which was corrected to 492.2 to account for local conditions)	1255 [1316 required maximum value]	0
	The above data showed that the APU from N8396A met the performance requirements for an overhauled APU. The data in the following row is from a test conducted as part of the accident investigation. This was not part of the manufacturer's normal test criteria and the test created a combined "worst condition" loading for the investigation. This loading applied the maximum rated (30kVA) electrical load during simultaneous main engine start conditions.						
APU from N8396A, with combined electrical and pneumatic loads.	69.0	1,250	72.5	53.8	467.2 (raw data, which was corrected to 501 to account for local conditions)	1341	30

¹ The following abbreviations are used in this report: Absolute pounds per square inch of pressure is shown by psia. Flow in pounds per minute is abbreviated as ppm.

² The altitude was selected due to FDR data showing that the 10th stage pneumatic bleed valves simultaneously opened at 13,000 feet. Bombardier maintenance training data showed that both 10th stage pneumatic bleed valves will open during an engine start. The test cell was located at 1,250 foot altitude, which led to acquiring the following data at that altitude.

Overall summary of valve characteristics (Values in parenthesis denote Bombardier published values):

	Left SOV	LCV	Isolation Valve	Right SOV
Annunciator switch opens at :	5.6 degrees (8 degrees)	4.8 degrees (5 degrees)	4.1-5.7 degrees (8 degrees)	3.8-6 degrees (8 degrees)
Pressure to open:	[Unable to function] (6-10psig)	[Not part of the modified ATP test performed.] (14-16psig)	2.7-3.5 psig (6-10psig)	3.5 psig (6-10psig)
Full open at:	[Unable to function]	74.4mA=84.3 deg (0.6mA under ATP min. acceptable)	7.29psig @ 85.6 degrees	7.4psig @ 84.7 degrees
Physical Damage	The valve was recovered from near the large hole in the aft fuselage. An impact hole was found in the diaphragm case.	No observable damage. White deposits found on surfaces.	Dented exterior tubes	None observed
Shaft movement:	Roughness in mid-travel (resisted thumb pressure)	Paused in opening at 3 points in travel (For reference, the ECU ATP found a 97.3mA output. Valve pauses were at application of 47.1mA, 47.5mA, & 71.1mA).	Linear response	During 2nd & 3rd openings, the valve stayed shut, then popped to 29.5 & 14.7 degrees, respectively (ref. 4.83psig)

Exhibit Section 2.0

Addendum to Systems Group Chairman's Factual Report:

Attached is a report that is titled *Systems Group Chairman's Factual Addendum, Pneumatics and Cabin Pressurization*. Page numbers from the original have been removed to prevent conflict with page numbering of the exhibit.

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Aviation Engineering Division
Washington, DC 20594

May 11, 2005

SYSTEMS GROUP CHAIRMAN'S FACTUAL ADDENDUM **PNEUMATICS AND CABIN PRESSURIZATION**

A. **ACCIDENT:** NTSB Identification DCA05MA003

LOCATION: Jefferson City, Missouri

DATE/TIME: October 14, 2004, about 10:15 pm (CDT)

AIRCRAFT: Bombardier Aerospace, Canadair Regional Jet, CRJ-200
 Northwest Airlink, Pinnacle Airlines Flight 3701

B. **GROUP MEMBERS**

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Memphis, Tennessee

C. SUMMARY

On October 14, 2004, at about 2215 central daylight time (CDT), N8396A, a Bombardier CL-600-2B19 operating as Pinnacle Airlines flight 3701 (d.b.a. Northwest Airlink) crashed in a residential area in Jefferson City, Missouri, about 2.5 miles south of the Jefferson City, Missouri, airport (JEF). The airplane was destroyed by the impact forces and a post crash fire. The two crew members were fatally injured. The flight was a repositioning flight from Little Rock, Arkansas (LIT) to Minneapolis-St. Paul, Minnesota (MSP) that had no passengers on board. There were no injuries on the ground.

This addendum to the Systems Group Chairman's Factual Report of February 9, 2005, contains information about the ground air supply connection panel, pneumatic system, and cabin pressurization systems.

D. DETAILS OF THE INVESTIGATION

D.1.0 GROUND AIR SUPPLY CONNECTION ACCESS PANEL

Bombardier personnel noted that the failure of the ground air supply connection will lead to a loss of bleed air pressure in the 10th stage pneumatic manifold. The access door for the ground air supply connection was found in the closed and latched position. The exterior color coat was bubbled or missing, but the underlying green primer was intact. The exterior primer on the panel was generally tanned without localized overheating where the circular check valve had been mounted. The interior paint on the door was also and slightly tanned overall, without localized heat damage from near the connection valve. The white paint on the composite interior wall was intact and not tanned. A label sticker was found that stated "GROUND AIR SUPPLY CONNECTION." The sticker had no yellowing, curled edges, or other evidence of thermal damage. (Figures 1 and 2)



Figure 1. Exterior of HP pneumatic supply access panel.



Figure 2. Interior of HP pneumatic supply access panel, showing missing duct, broken interior panel, intact sticker, and white paint.

The duct that had attached to the composite interior wall of the compartment had broken away. Dents were observed along the aft surfaces of the duct that had been mounted forward of the ground supply duct. The skin of the airframe surrounding the general area was displaced inward from a smooth contour and the fuselage frames were broken. The missing duct had been next to where the right aircraft engine and pylon had separated and a large opening in the aft fuselage had been created.

D.2.0 CABIN PRESSURIZATION

Data from the maintenance training manual and flight data recorder were combined to calculate the rate of descent for the airplane and the rate of cabin depressurization (also known as the ascent rate).

The Canadair Regional Jet 100/200 Airframe/Engine Maintenance Training Manual showed that the 10th stage bleed valves are solenoid controlled and pneumatically actuated in ducts that provide air to the cabin pressurization system. The flight 3701 flight data recorder (FDR) parameter for the valve positions showed each to be open until time (UTC) 02:55:06.40, when the left valve closed as the engine speeds slowed through about 35% N1 and 60% N2. The right valve was recorded closing at 02:55:14.40 when the airplane altitude was 37,818 feet and this time/altitude was used as the beginning of depressurization in the following calculations. The FDR parameter for the load control valve (LCV³) recorded a transient opening at an altitude of 20,333 feet (UTC 03:02:30.15), and then remained open after the airplane descended below 13,115 feet (UTC 03:07:05.15). Dividing the altitude change by the time, the descent rate of the airplane during these periods calculated to be 2,369 feet per minute (fpm) to 20,333 feet and 2,065 fpm overall.

The maintenance training manual shows that the cabin pressurization system is digitally controlled to maintain an 8,000 (+/-100) foot cabin altitude. The FDR does not capture cabin altitude data, but does have a discrete (CABIN PRESSURE WARN) to record when the cabin altitude warning signal is provided to the crew alerting system (CAS). The maintenance training manual shows that the engagement and disengagement should be at a cabin altitude of 10,000 feet.

The flight 3701 FDR did not record that the cabin pressure warning was active prior to the airplane reaching 41,000 feet. The cockpit voice recorder (CVR) recorded the first actuation of the cabin pressure warning at 02:56:47.40. The FDR showed that the cabin pressure warning was active when the FDR recording resumed, as the airplane descended from 30,000 feet. The cabin altitude warning was reset in the FDR recording when the airplane descended through 10,020 feet (UTC 03:09:05.15).

The maintenance training manual shows that the cabin oxygen masks are deployed at a cabin altitude of 14,000 feet and that the FDR records this signal. The FDR from flight 3701 showed that the mask signal was not present until the airplane descended to an altitude of 22,531 feet (UTC 03:01:45.15). Dividing the cabin altitude between 8,000 feet (UTC 02:55:14.40) and 14,000 feet (UTC 03:01:45.15) by the 6.50 minutes from closure of the right valve resulted in an average cabin depressurization rate of 923 fpm.

³ The LCV is mounted on the APU outlet and is functionally located between the APU and the 10th stage bleed valves.

An additional data point related to altitude was a crew comment recorded by the CVR, that the altitude was 15,400 feet, at 03:03:57.15.

Figure 3 (below) displays a combination of FDR data for aircraft altitude, the cabin pressure warning, and deployment of the oxygen masks. Connecting the cabin altitude data points with a straight line and extending the line to the recorded aircraft altitude, the line crosses at about when the airplane was at 16,423 feet.

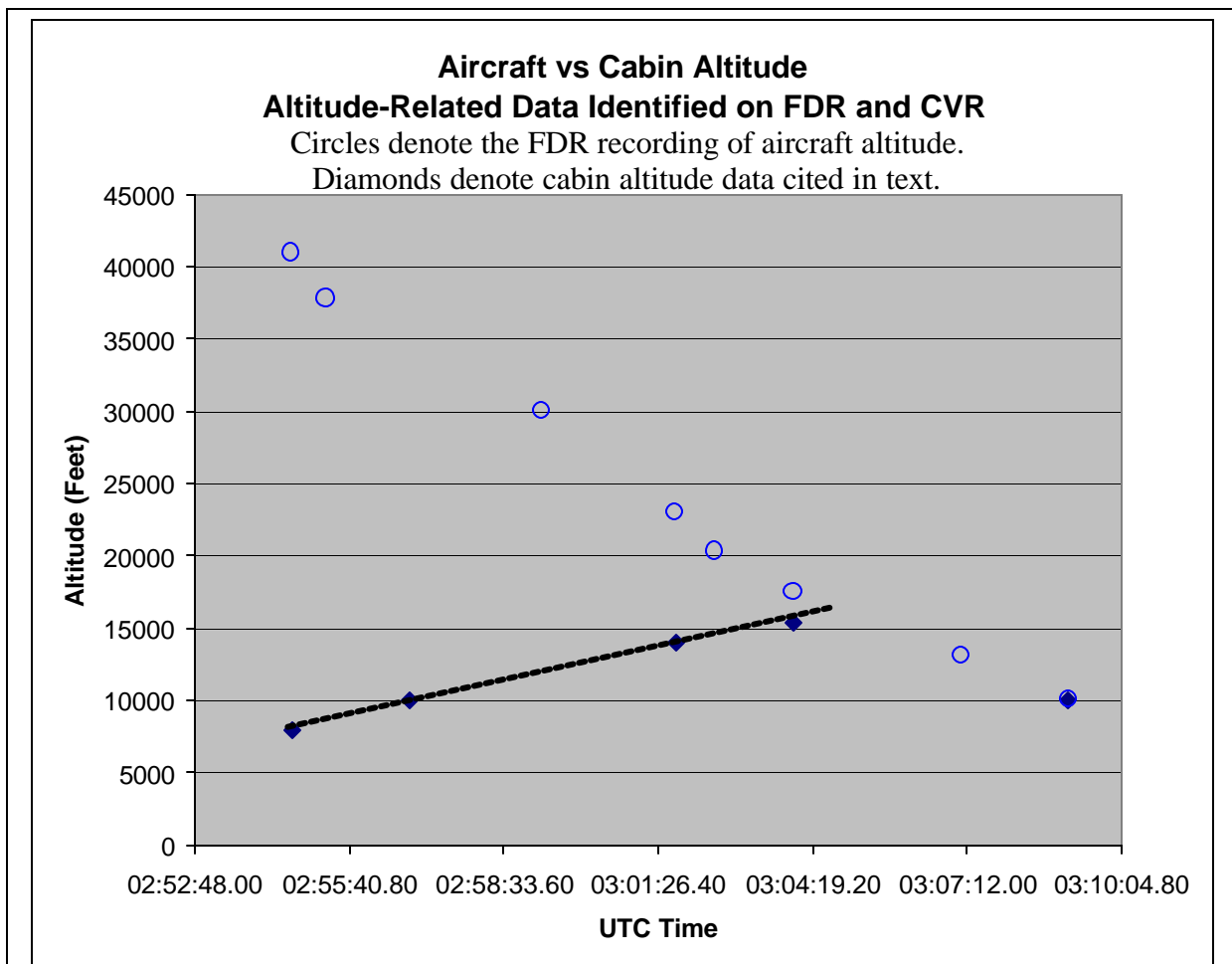


Figure 3. The chart shows the altitude-related FDR and CVR data for the cabin pressure and the airplane altimeter that are cited in the text. A line connects the second and third diamonds, which were automated and recorded values for the cabin pressure warning and deployment of cabin oxygen masks. The line has been extended to the first diamond (nominal cabin altitude when bleed valve closed) and to the recorded aircraft altimeter values, which it crosses at about 16,500 feet. The fourth diamond is the crew reference to altitude and the fifth is the recorded reset of the cabin pressure warning (at nominal 10,000 feet msl). Airplane altitude data shown in circles was obtained from the FDR recording of the airplane altimeter.

Data pertaining to cabin altitude changes was also obtained from Bombardier flight testing of a Global Express airplane and the data is attached.⁴ Data from a flight test of June 22, 1998, (Report RAH-0700-104, Page A-21, Rev A) showed the results of shutting airflow to the cabin at an aircraft altitude of slightly over 51,000 feet, with an initial cabin altitude of 7,230 feet. Following loss of pressurization the test airplane remained at 51,000 feet for less than 100 seconds, then descended at about 9700 feet per minute (fpm) to 10,000 feet above sea level. During this period, the cabin ascended at an average rate of 2,032 fpm to reach a maximum cabin altitude. As the airplane descended through 17,052 feet, the cabin altitude also began to decrease.

Charted data from a second flight test (Doc. RAH-GG100-306, Page 82, Dated 2003-04-29) showed the results of a similar test that was conducted on a Challenger 300 (also known as a BD100), conducted from about 45,000 feet above sea level. The scale of the chart prevented interpretation with the accuracy of the 1998 test results, but was similar. The cabin altitude ascended initially at about 1,800 fpm and the rate of ascent decreased to about 1,000 fpm when the cabin altitude and aircraft altitude converged. The maximum cabin altitude was 17,168 feet.

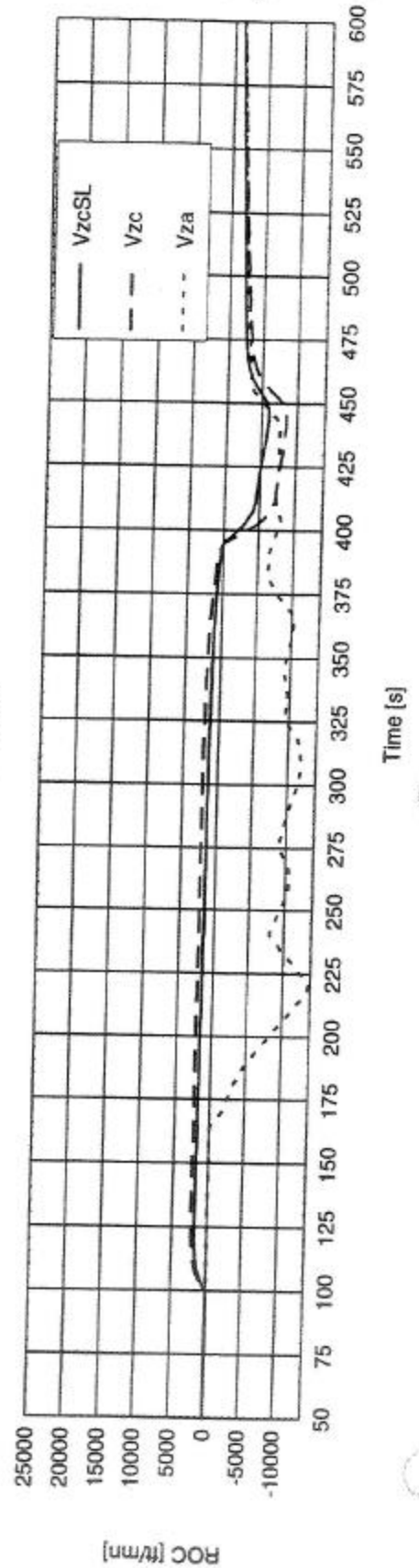
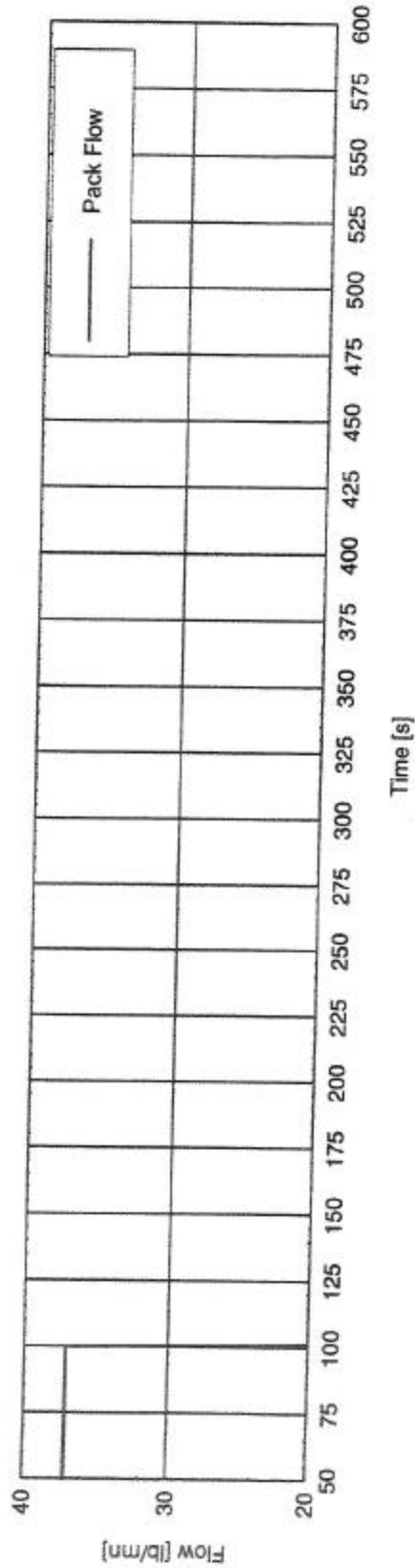
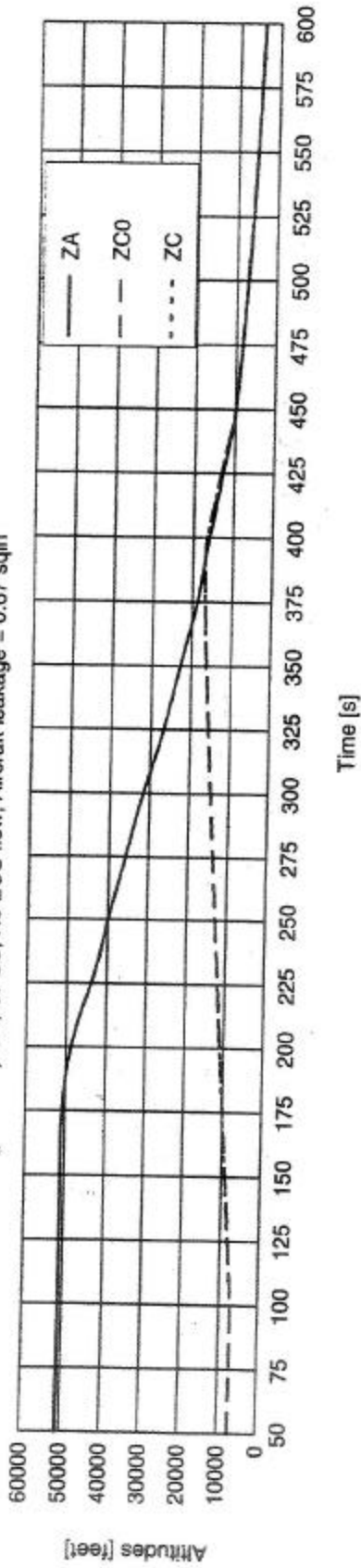
⁴ Equivalent data from the certification of the Regional Jet was not located. The CRJ fuselage volume is similar to that of the Global Express and is between the larger Global Express and smaller Challenger in both engine size and fuselage volume. The data from each of those airplanes had similarities in depressurization rates and maximum cabin altitudes achieved. (See Attachment)

ATTACHMENT 1

Bombardier Global Express flight test results shown on
Report RAH-0700-104, Page A-21, Rev A

Mon Jun 22 1998

Flight 187, GX, CPCS, No ECS flow, Aircraft leakage = 0.67 sqin



RAH-C700-104 de VA
Page A-21

ATTACHMENT 2

Bombardier Challenger 300 flight test results shown on
Doc. RAH-GG100-306, Page 82, Dated 2003-04-29

BOMBARDIER
AEROSPACE

DOC: RAH-GG100-306
REV: -- 82
PAGE: 82
DATE: 2003-04-29

Appendix 8 : Complete loss of fresh air

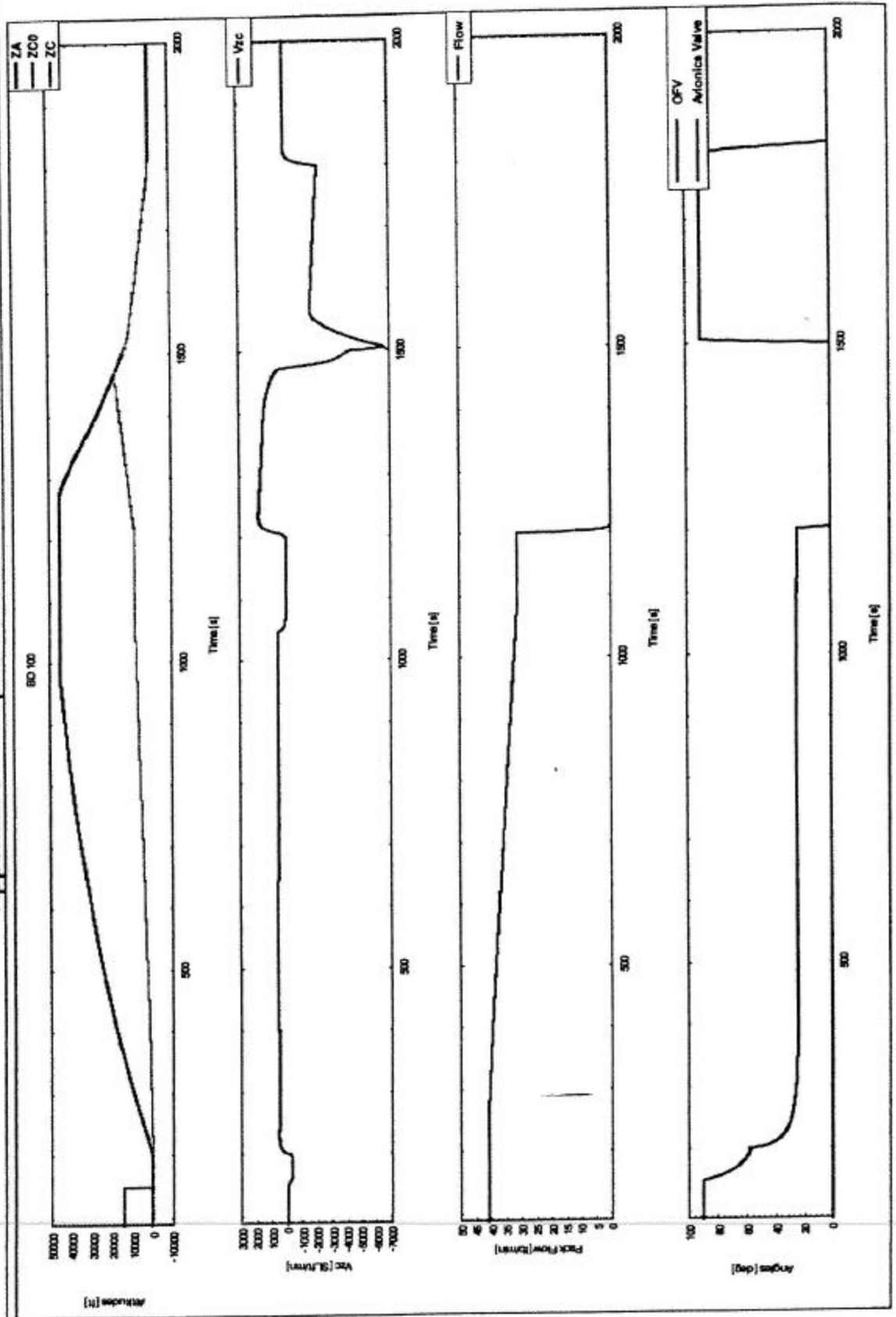


Figure 38 : Complete loss of fresh air

Exhibit Section 3.0

Pneumatic Modeling by Bombardier:

Bombardier created a digital model of the CRJ pneumatic system and spreadsheets containing the results of using that model are attached.

Exhibit page 16 compares the digital model with actual flight test results.

Exhibit pages 17-19 describe the test cases.

Exhibit pages 20-21 show the inputs used for each case that was studied.

Exhibit page 22 contains the results of the cases studied.

MODEL VALIDATION RESULTS (Page 1 of 1)

Simulation Case	TEST REPORT CASE	TEST Ambient Pressure psia	TEST 10th stage LH Bleed Air Pressure psig	TEST 10th stage LH Bleed Air Pressure psia	Simulation 10th stage LH Bleed Air Pressure psia	TEST LH AIS TOTAL Pressure psia	Simulation LH AIS TOTAL Pressure psia	TEST LHS (see note 1) Delta P psid	Simulation LHS (see note 1) Delta P psid	TEST 10th stage RH Bleed Pressure psig	TEST 10th stage RH Bleed Air Pressure psia	Simulation 10th stage RH Bleed Air Pressure psia	TEST RH AIS TOTAL Pressure psia	Simulation RH AIS TOTAL Pressure psia	TEST RHS (see note 1) Delta P psid	Simulation RHS (see note 1) Delta P psid
V3 Minimal	FLT 1219, Dec 17 2001, A/C 1002 , w/125	11.22	31.5	18.12	50.3	12	13	6.12	1.3	31.5	15.12	16.11	12.5	13.01	3.22	3.16
V6 Minimal	FLT 1223, April 11 2005, A/C 1002 , w/122	13.13	32.5	16.23	18.8	10	11.8	6.23	1	29	12.13	11.38	10	11.08	2.13	3.29

Simulation Case	TEST REPORT	TEST Ambient Temperature deg F	TEST 10th stage LH Bleed Air Temperature deg C	TEST 10th stage LH Bleed Air Temperature deg F	Simulation 10th stage LH Bleed Air Temperature deg F	TEST LHS APU EGT Temperature deg F	Simulation LHS APU EGT Temperature deg F	TEST RHS APU EGT Temperature deg F	Simulation RHS APU EGT Temperature deg F	TEST 10th stage RH Bleed Temperature deg C	TEST 10th stage RH Bleed Air Temperature deg F	Simulation 10th stage RH Bleed Air Temperature deg F
V3 Minimal	FLT 1219, Dec 17 2001, A/C 1002 , w/125	39.1	225	131	140	1081	1060	1089	1062	220	128	141
V6 Minimal	FLT 1223, April 11 2005, A/C 1002 , w/122	51.2	236	151	141	1084	1061	1094	1083	238	160	156

Note 1 : The 10th stage bleed pressures were static pressures , and the AIS pressures were total.

LIST OF CASES TO BE MODELED (Page 1 of 3. The rows align with data on the following two pages.)

LIST OF CASES		ENGINE STATUS		
CASE IDENTIFER	CASE DESCRIPTION	LH ENGINE	RH ENGINE	APU
V4	Validation - Normal cross-bleed engine start on ground. Compare with an actual ground test.	Pb = 60 psia, Tb= 498 F	RH Engine Start	OFF LINE
PF.7	What is the excess pneumatic engine capability at 41000 feet? (Can we rule out a leak?)	Pb = 60 psia, Tb= 498 F	Pb = 60 psia, Tb= 498 F	OFF LINE
APU.5	Maximum altitude this APU could have pressurized cabin to 10000 feet	OFF LINE	OFF LINE	ON LINE
APU.6	Maximum altitude this APU could have pressurized cabin to 8000 feet?	OFF LINE	OFF LINE	ON LINE
APU.8a	How much restriction would the LCV need, to have the 13000 feet performance seen in data?	OFF LINE	RH Engine Start	ON LINE
APU.8b	Same at 5000 feet	OFF LINE	RH Engine Start	ON LINE
APU.9a	Amount of leakage required to get 13000 feet performance seen, with recorded APU output.			

LIST OF CASES TO BE MODELED (Page 2 of 3. The rows align with data on the previous and following pages.)

[illegible]

LIST OF CASES TO BE MODELED (Page 3 of 3. The rows align with data on the previous two pages.)

AIRCRAFT AMBIENT CONDITIONS					APU DECK INPUT CONDITIONS					CABIN INPUTS		COMMENTS
MACH NO.	ALTITUDE (FFET)	AMBIENT PRESS (psia)	AMBIENT TEMP (DEG F)	RELATIVE HUMIDITY (0-100)	SHAFT HORSE POWER	APU RATING CODE	APU OPERATI NG MODE	ENGINE HEALTH (Minimum= 1)	VGD STATUS (Open=1)	DESIRED CABIN TEMPERA TURE (DEG F)	DESIRED CABIN PRESSURE (PSIA)	
0	0	TBD	TBD	TBD	29.5	23	3	1	1	75	14.97	Used the APU validation data to compare the pressure drop from the 10th stage bleed pressure to the ATS in order to be confident in the CBS prediction.
0.3	41000	2.592	-52.8	0	29.5	23	3	1	1	75	10.92	Estimated maximum aircraft leakage at 41000 feet is 8.6 lb/min . Therefore the engines should be able to pressurize the cabin at this altitude
0.3	TBD	TBD	TBD	TBD	29.5	23	3	1	1	75	10.11	Answer is 20000 feet , since APU deck does not predict above this Altitude .
0.3	TBD	TBD	TBD	TBD	29.5	23	3	1	1	75	10.92	Answer is 20000 feet , since APU deck does not predict above this Altitude .
0.3	13000	8.932	8.6	40	29.5	23	3	1	1	75	14,52	
0.3	5000	12.23	31.3	40	29.5	23	3	1	1	75	14,52	

Note: For “TBD” see parameter used for the individual test cases.

INPUTS LIST (Page 1 of 2. The rows align with the following page.)

LIST OF CASES			ENGINE STATUS			Valve Positions									
CASE NO.	CASE IDENTIFIER	CASE DESCRIPTION	LH ENGINE	RH ENGINE	APU	LH Bleed Valve	LH 100% Stage 5CV	LH A15 Valve	Isolation Valve	RH 100% Stage 5CV	RH A15 Valve	RH Bleed Valve	APU LCV	LH ACV Prescv	RH ACV Prescv
VALIDATION RUNS			LH Engine Start	OFF LINE	ON LINE	CLOSED	OPEN	OPEN	CLOSED	OPEN	OPEN	CLOSED	CLOSED	CLOSED	CLOSED
1	V3 Mainline LHS	FLT 1219, Dec 17 2004, A/C 7002, w6725	LH Engine Start	RH Engine Start	ON LINE	CLOSED	OPEN	OPEN	CLOSED	OPEN	OPEN	CLOSED	OPEN	CLOSED	CLOSED
2	V3 Mainline RHS	FLT 1219, Dec 17 2004, A/C 7002, w6725	OFF LINE	OFF LINE	ON LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	OPEN	CLOSED	OPEN	CLOSED	CLOSED
3	V4 Mainline LHS	FLT 1223, April 11 2005, A/C 7002, w6722	OFF LINE	OFF LINE	ON LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	OPEN	CLOSED	OPEN	CLOSED	CLOSED
4	V4 Mainline RHS	FLT 1223, April 11 2005, A/C 7002, w6722	OFF LINE	OFF LINE	ON LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	OPEN	CLOSED	OPEN	CLOSED	CLOSED
LEAKAGE EXAMINATIONS:															
5	LE 1a	Failure at engine - cross bleed engine start, LH open engine bleed check valve 1, 13000 feet	LH Engine Start	Rh = 60 psia Th = 460 F	OFF LINE	OPEN	OPEN	CLOSED	OPEN	OPEN	CLOSED	OPEN	CLOSED	CLOSED	CLOSED
6	LE 2b	Same at 5000 feet	LH Engine Start	Rh = 60 psia Th = 460 F	OFF LINE	OPEN	OPEN	CLOSED	OPEN	OPEN	CLOSED	OPEN	CLOSED	CLOSED	CLOSED
7	LE 4a	Failure at engine - APU engine start attempt at 13000 feet, but with RH open engine bleed check valve	LH Engine Start	OFF LINE	ON LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	CLOSED	OPEN	OPEN	CLOSED	CLOSED
8	LE 4b	Same at 5000 feet	LH Engine Start	OFF LINE	ON LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	CLOSED	OPEN	OPEN	CLOSED	CLOSED
9	LE 5a	Failure at engine - APU engine start attempt at altitude, but with open RH engine starter valve? 13000 feet	LH Engine Start	OFF LINE	ON LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	CLOSED	OPEN	OPEN	CLOSED	CLOSED
10	LE 5b	Same at 5000 feet	LH Engine Start	OFF LINE	ON LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	CLOSED	OPEN	OPEN	CLOSED	CLOSED
PACK FAILURE EXAMS:															
11	PF 1a	Two open packs? 13000 feet	LH Engine Start	Rh = 60 psia Th = 460 F	OFF LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	CLOSED	OPEN	CLOSED	OPEN	OPEN
12	PF 1b	Same at 5000 feet	LH Engine Start	Rh = 60 psia Th = 460 F	OFF LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	CLOSED	OPEN	CLOSED	OPEN	OPEN
13	PF 2a	Two open packs? 13000 feet	LH Engine Start	Rh = 60 psia Th = 460 F	OFF LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	CLOSED	OPEN	CLOSED	OPEN	OPEN
14	PF 2b	Same at 5000 feet	LH Engine Start	Rh = 60 psia Th = 460 F	OFF LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	CLOSED	OPEN	CLOSED	OPEN	OPEN
15	PF 3a	Two open packs? 13000 feet	LH Engine Start	Rh = 60 psia Th = 460 F	OFF LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	CLOSED	OPEN	CLOSED	OPEN	OPEN
16	PF 3b	Same at 5000 feet	LH Engine Start	Rh = 60 psia Th = 460 F	OFF LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	CLOSED	OPEN	CLOSED	OPEN	OPEN
17	PF 4a	Two open packs? 13000 feet	LH Engine Start	Rh = 60 psia Th = 460 F	OFF LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	CLOSED	OPEN	CLOSED	OPEN	OPEN
18	PF 4b	Same at 5000 feet	LH Engine Start	Rh = 60 psia Th = 460 F	OFF LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	CLOSED	OPEN	CLOSED	OPEN	OPEN
19	PF 6a	Two open packs? 13000 feet	LH Engine Start	Rh = 60 psia Th = 460 F	OFF LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	CLOSED	OPEN	CLOSED	OPEN	OPEN
20	PF 6b	Same at 5000 feet	LH Engine Start	Rh = 60 psia Th = 460 F	OFF LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	CLOSED	OPEN	CLOSED	OPEN	OPEN
APU CAPABILITY EXAMS:															
21	APU GND	APU engine start capability in-flight at 13000 feet HW APU deck	LH Engine Start	OFF LINE	ON LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	CLOSED	CLOSED	OPEN	CLOSED	CLOSED
22	APU 1	APU engine start capability in-flight at 13000 feet HW APU deck	LH Engine Start	OFF LINE	ON LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	CLOSED	CLOSED	OPEN	CLOSED	CLOSED
23	APU 2	APU engine start capability in-flight at 5000 feet HW APU deck	LH Engine Start	OFF LINE	ON LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	CLOSED	CLOSED	OPEN	CLOSED	CLOSED
24	APU 4	Maximum altitude the APU could have been able to start an engine at?	LH Engine Start	OFF LINE	ON LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	CLOSED	CLOSED	OPEN	CLOSED	CLOSED
25	APU7 LCV 21 Deg	Minimum LCV angle to start engine at 13000 feet? LCV was manually ramped down to 21.2 deg	LH Engine Start	OFF LINE	ON LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	CLOSED	CLOSED	OPEN	CLOSED	CLOSED
26	APU7 LCV 8 Deg	Minimum LCV angle to start engine at 13000 feet? LCV was manually ramped down to 8 deg	LH Engine Start	OFF LINE	ON LINE	CLOSED	OPEN	CLOSED	OPEN	OPEN	CLOSED	CLOSED	OPEN	CLOSED	CLOSED

NOTE 1 : MAXIMUM ALTITUDE THAT CAN BE RUN WAS 20000 FEET , SINCE HW DECK DOESNT PREDICT BLEED EXTRACTION PERFORMANCE ABOVE THIS ALTITUDE

INPUTS LIST (Page 2 of 2. The rows align with the following page.)

AIRCRAFT AMBIENT CONDITIONS				APU DECK INPUT CONDITIONS				CABIN INPUTS			
MACH NO.	ALTITUDE (FEET)	AMBIENT PRESS (PSI)	AMBIENT TEMP (DEG F)	RELATIVE HUMIDITY (%-100)	SHAFT HOSE POWERIN	APU RATING CODE	APU OPERATING MODE	ENGINE HEALTH (MINIMUM=1)	W/O STATUS (OCCUP=1)	DESIRED CABIN TEMPERATURE (DEG F)	DESIRED CABIN PRESSURE (PSIA)
0	1300	14.22	39.1	40	29.5	23	3	1	1	75	14.46
0	1300	14.22	39.1	40	29.5	23	3	1	1	75	14.46
0	1300	13.73	57.2	40	29.5	23	3	1	1	75	14.46
0	1300	13.73	57.2	40	29.5	23	3	1	1	75	14.46
0.3	13000	8.934	8.6	40	29.5	23	3	1	1	75	14.54
0.318	5000	12.197	31.3	40	29.5	23	3	1	1	75	14.97
0.3	13000	8.934	8.6	40	29.5	23	3	1	1	75	14.54
0.318	5000	12.197	31.3	40	29.5	23	3	1	1	75	14.97
0.3	13000	8.934	8.6	40	29.5	23	3	1	1	75	14.54
0.318	5000	12.197	31.3	40	29.5	23	3	1	1	75	14.97
0.3	13000	8.934	8.6	40	29.5	23	3	1	1	75	14.54
0.318	5000	12.197	31.3	40	29.5	23	3	1	1	75	14.97
0	600	14.38	48	40	29.5	23	4	1	1	75	14.7
0.3	13000	8.934	8.6	40	29.5	23	3	1	1	75	14.54
0	600	14.38	48	40	29.5	23	4	1	1	75	14.7
0.318	13000	8.934	8.6	40	29.5	23	3	1	1	75	14.54
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0.3	5000	12.197	31.3	40	29.5	23	3	1			

RESULTS OF MODELING (Page 1 of 1)

LIST OF CASES		AIR TURBINE STARTER RESULTS						COMMENTS	
CASE NO.	CASE IDENTIFIER	CASE DESCRIPTION	ATS Nozzle Inlet Pressure (psia)	ATS Nozzle Inlet Pressure (psia)	ATS Inlet Temperature (deg F)	ATS Inlet Flow (lb/min)	ATS Corrected Flow (lb/min)	ATS Pressure Ratio	
VALIDATION RUNS									
1	V3 Winair LHS	FLT 1219 Dec 17 2004 A/C 7002, w/6725	43	28.8	464	59.8	27.57	3.02	refer to validation summary table
2	V3 Winair RHS	FLT 1219 Dec 17 2004 A/C 7002, w/6725	43	28.8	460	60	27.57	3.02	refer to validation summary table
3	V4 Winair LHS	FLT 1223 April 11 2005 A/C 7002, w/6722	41.8	28.1	484	58.1	27.57	3.04	refer to validation summary table
4	V4 Winair RHS	FLT 1223 April 11 2005 A/C 7002, w/6722	41.1	27.4	496	56.8	27.57	2.99	refer to validation summary table
LEAKAGE EXAMINATIONS:									
5	LE 1a	Failure at engine - Cross bleed engine start, LH open engine bleed check valve 1, 13000 feet	38.2	29.3	528	51.9	27.57	4.28	LH open engine bleed check valve flow = 12.4 lb/min
6	LE 2b	Failure at engine - APU engine start attempt at 13000 feet, but with RH open engine bleed check valve	38.4	26.2	528	52.2	27.57	3.15	LH open engine bleed check valve flow = 10.5 lb/min
7	LE 4a	Same at 5000 feet	26.6	17.7	462	37.5	27.57	2.98	RH open engine bleed check valve flow = 13.6 lb/min
8	LE 4b	Same at 5000 feet	41.3	29.1	494	49.1	27.57	2.69	RH open engine bleed check valve flow = 10.5 lb/min
9	LE 5a	Failure at engine - APU engine start attempt at altitude, but with open RH engine starter valve?	17.4	8.5	481	24.5	27.57	1.97	RH Air Starter flow = 24.8 lb/min
10	LE 5b	Same at 5000 feet	24	11.8	483	33.5	27.57	1.97	RH Air Starter flow = 33.0 lb/min
PACK FAILURE EXAMS:									
11	PF 1a	PACK failure - Cross bleed engine start, 13000 feet	28.6	19.7	468	40.17	27.57	3.2	LH pack flow = 20.0 lb/min
12	PF 1b	Same at 5000 feet	29.1	16.9	473	40.7	27.57	2.39	RH pack flow = 27.0 lb/min
13	PF 2a	PACK failure - Cross bleed engine start, ONE open pack? 13000 feet	35.8	26.9	475	50	27.57	4	RH pack flow = 32.2 lb/min
14	PF 2b	Same at 5000 feet	36.2	24.0	480	50.2	27.57	2.96	RH pack flow = 26.5 lb/min
15	PF 3a	PACK failure - APU engine start with 13000 feet	14.6	5.7	452	20.4	27.13	1.64	LH pack flow = 14.9 lb/min
16	PF 3b	Same at 5000 feet	20.3	8.1	469	28.1	27.21	1.67	RH pack flow = 14.6 lb/min
17	PF 4a	PACK failure - APU engine start with ONE open pack? 13000 feet	20.8	11.9	457	29.4	27.57	2.33	RH pack flow = 20.1 lb/min
18	PF 4b	Same at 5000 feet	28.5	16.3	478	39.6	27.57	2.34	RH pack flow = 27.3 lb/min
19	PF 6a	Open Ground Check Valve during APU engine start capability (Ground)	25	10.6	573	33.1	27.42	1.73	RH pack flow = 32.2 lb/min
20	PF 6b	Open Ground Check Valve during engine start capability (13000 ft)	15.8	6.9	540	21.15	27.48	1.76	RH pack flow = 18.5 lb/min
APU CAPABILITY EXAMS:									
21	APU ON/O	APU engine start capability (Ground) at 5000 feet	43.3	28.9	493	59.9	27.57	3	Ground valve flow = 49.3 lb/min
22	APU 1	APU engine start capability in-flight at 13000 feet	28.3	19.4	465	39.8	27.57	3.17	Demonstration of APU capability
23	APU 2	APU engine start capability in-flight at 5000 feet	37.5	25.3	485	52.1	27.57	3.07	Demonstration of APU capability
24	APU 4	Demonstrate altitude flow APU should have been able to start an engine at?	22.2	15.4	444	31.6	27.57	3.29	Maximum Altitude is 20000 feet
25	APU7 LCV 21 Deg	Minimum LCV angle to start engine at 13000 feet? LCV inputs were gradually closed to 21.2 deg	15.5	6.6	463	21.6	27.13	1.73	Refer to note 1
26	APU7 LCV 8 Deg	Minimum LCV angle to start engine at 13000 feet? LCV was manually ramped down to 8 deg	9.6	0.7	433	7.34	14.7	1.07	Refer to note 2

NOTE 1 : MAXIMUM ALTITUDE THAT CAN BE RUN WAS 20000 FEET. SINCE HW DECK DOESN'T PREDICT BLEED EXTRACTION PERFORMANCE ABOVE THIS ALTITUDE

In accordance with AFM (CSA A-012), maximum altitude for engine start using APU bleed is 13,000 ft.

NOTE 2 : Valve operation under low pressure operation (less than fully open pressure) has not been validated under the conditions stated and therefore relies on the assumption that the valve area varies linearly from the fully open pressure to fully closed pressure and maintains its position during intermediate values.

NOTE: Honeywell Aerospace Engine Systems & Accessories information for the Air Turbine Starter, ATS100-395H provides "Estimated Generalized Performance" for the starter. The data relates starter torque to corrected speed (RPM) at various corrected airflow ratios (starter inlet pressure divided by starter discharge pressure. Starter performance is not shown at ratios of less than 2.0:1.

Exhibit Section 4.0

Auxiliary Power Unit (APU) and Pneumatics Background Data:

The following page pertain to the APU and pneumatic systems and has been copied from the Pinnacle Airlines Flight Crew Operating Manual.

Pinnacle Airlines**Northwest Airlink****CANADAIR REGIONAL JET**

FLIGHT CREW OPERATING MANUAL—Volume 1

AUXILIARY POWER UNIT

The auxiliary power unit (APU) is a gas-turbine engine equipped with a gearbox driving an oil-cooled 30-kVA, AC generator. The APU's primary function is to drive the AC electrical generator. The APU has an integral bleed port, supplying pneumatic power to drive the main engine air-turbine starters or the air-cycle machines within the air-conditioning packs (Figure 1-44).

The APU is in a fireproof enclosure in the tail of the airplane. An APU air-inlet door is on the top of the fuselage. APU exhaust gases pass through a muffler to an outlet beneath the right engine. Oil cooler air exhaust exits through the APU exhaust. Electrical power from the APU battery starts the APU. Fuel from both wing tanks is used to operate the APU. The APU's control circuits are fed from the main battery.

An electronic control unit (ECU) controls the APU. The ECU monitors all sensors and switches, sets up the appropriate fuel acceleration and temperature schedules, and relays appropriate operating data to the EICAS displays. The APU control system ensures electrical load priority by reducing bleed airflow when exhaust gas temperature limits are approached.

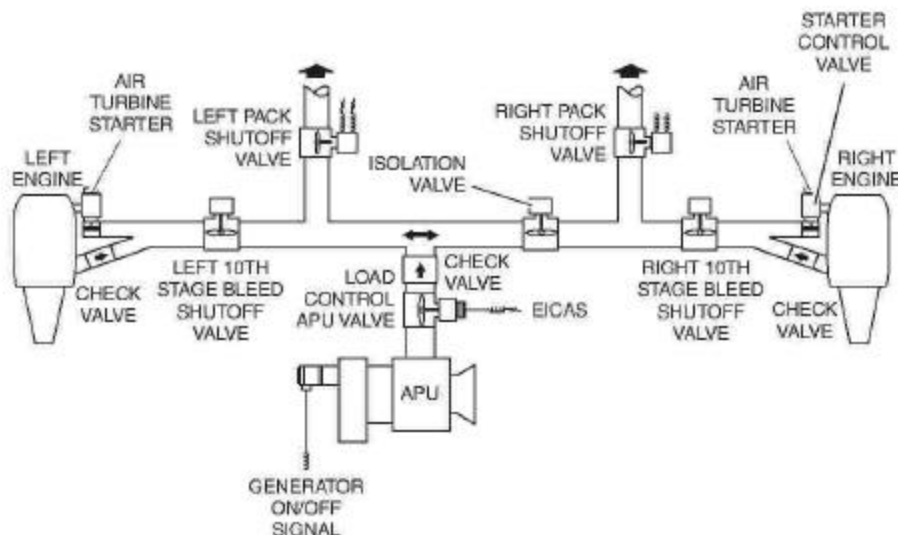
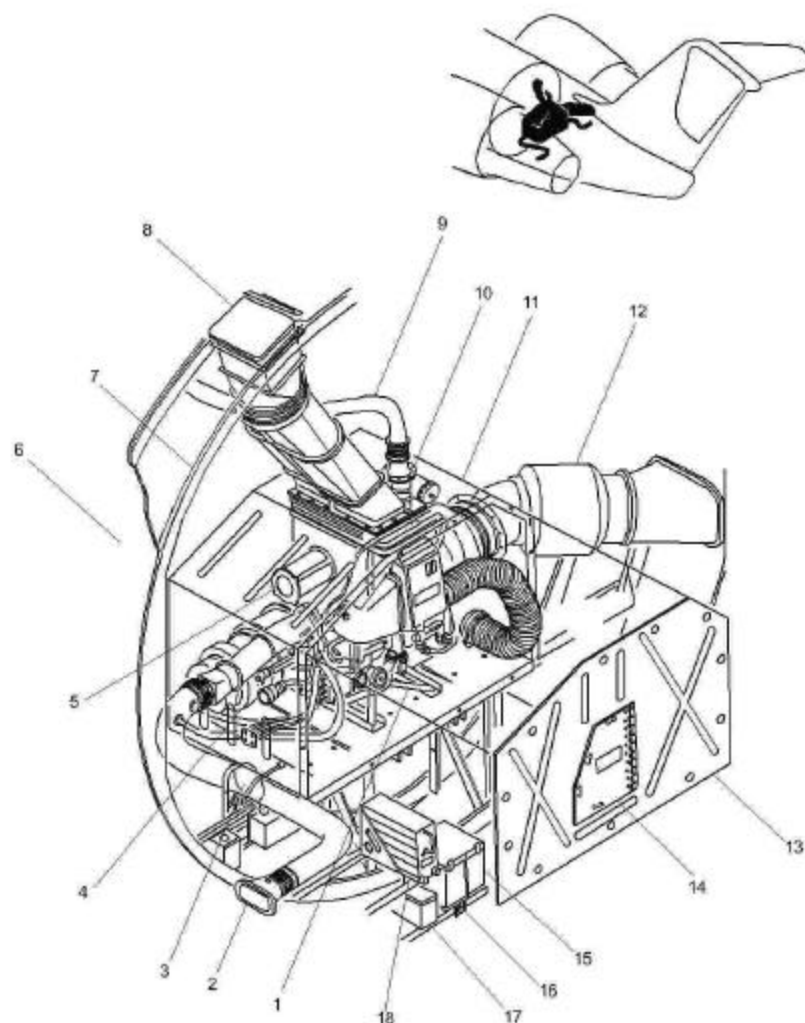


Figure 1-44 APU Bleed-Air Distribution

Exhibit Section 5.0

Auxiliary Power Unit (APU) and Pneumatics Background Data:

The following pages pertain to the APU and pneumatic systems and have been copied from the Canadair Regional Jet 100/200 Airframe/Engine Maintenance Training Manual.



LEGEND

- | | |
|---------------------------|----------------------------|
| 1. Support Skid | 10. Load Control Valve |
| 2. Cooling Air Inlet | 11. APU Enclosure |
| 3. Cooling Air Inlet Duct | 12. Exhaust Muffler |
| 4. AC Generator | 13. APU Comp. Access Panel |
| 5. Starter | 14. Service Door |
| 6. Aircraft Skin | 15. APU Battery |
| 7. Frame | 16. Cut-Off Switch |
| 8. APU Intake Door | 17. Main Battery |
| 9. Bleed Air Duct | 18. ECU |

R2449001

Figure 1 - APU Installation

49 - Auxiliary Power

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DESIGN FUNCTION

Refer to Figure 2.

The APU forms part of the aircraft electrical and pneumatic systems and provide the following functions:

- The primary function is to drive a 30 kVA generator that supplies back-up electrical power to the aircraft throughout its operating envelope, when required.
- The secondary function is to provide pneumatic power to operate the aircraft air conditioning systems and for main engine starts on the ground and in flight up to 13 000 ft.

49 - Auxiliary Power

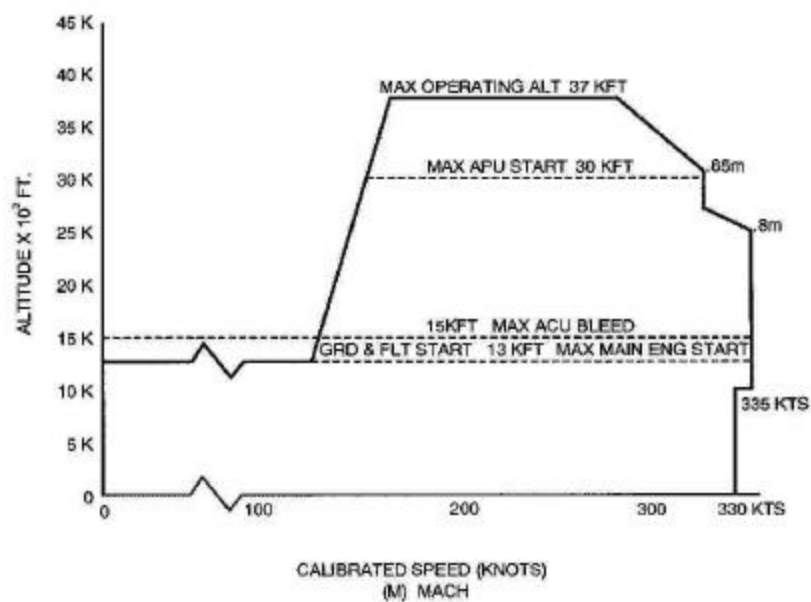
3 June 2002

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AIRFRAME/ENGINE MAINTENANCE TRAINING MANUAL

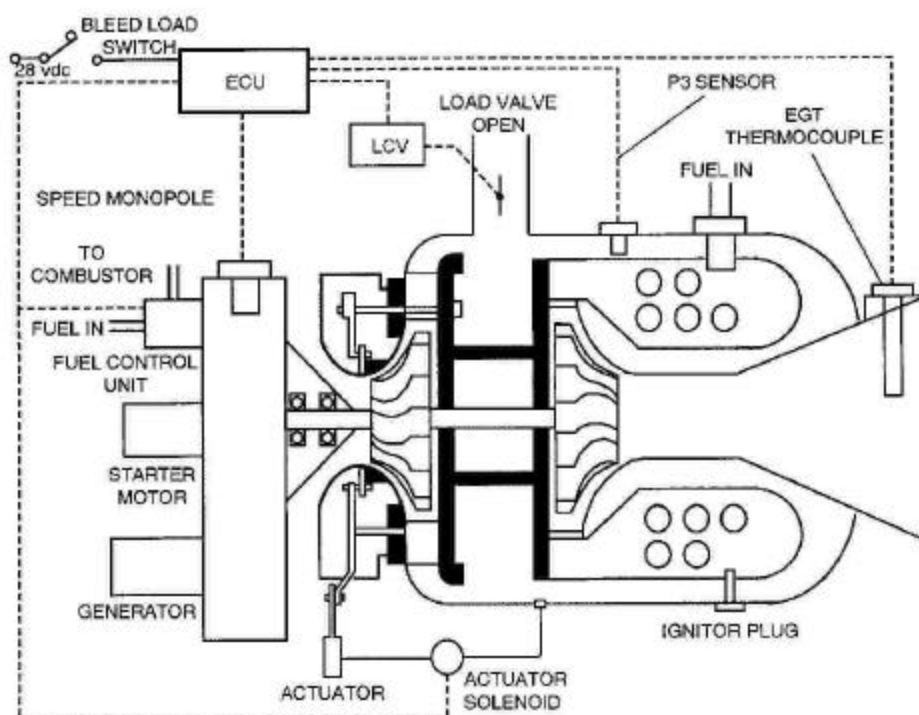


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Figure 3 - Operating Envelope

49 - Auxiliary Power

3 June 2002



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Figure 35 - Bleed Load Control

49 - Auxiliary Power

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EICAS SECONDARY DISPLAY ANTI-ICE SYNOPTIC PAGE

EICAS SECONDARY DISPLAY STATUS PAGE

EICAS SECONDARY DISPLAY ECS SYNOPTIC PAGE

Figure 2 - Bleed Air - Control and Indication

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